

Microbial Formulations and Enzymatic Analysis for Development of Sustainable Biofertilizers from Organic Wastes

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Structured Abstract

Background: Environmental issues like eutrophication, biodiversity loss, and soil degradation have been brought on by the overuse of synthetic fertilisers. However, when incorrectly disposed of, nutrient-rich organic wastes such as oil palm husk, rice straw, and black soldier fly frass are underutilised and contribute to pollution. This study aims to utilize microbial and enzymatic technologies to convert these organic wastes into biofertilizers that support crop qualities, and sustainable agriculture by using microbial and enzymatic technologies.

Methods: Organic wastes such as rice straw, coconut husk, oil palm husk, empty fruit bunch (EFB), sugarcane molasses, and black soldier fly frass (BSF) were treated via microbial fermentation by a consortium that included *Bacillus subtilis*, *Candida utilis*, *Rhizobium spp.*, and others. To assess enzymatic activities such cellulase, protease, and laccase, enzyme-specific agar experiments were performed. Red amaranth (*Amaranthus cruentus*) plant growth trials were conducted to evaluate the effectiveness of the created biofertilizers in comparison to synthetic fertilisers. To find the best formulations, statistical analysis was conducted using the Box–Behnken Design (BBD) and ANOVA.

Results: Significant gains in shoot, root, and overall plant length were shown by biofertilizers with increased ratios of EFB, sugarcane molasses, and black soldier fly frass. High nutritional release potential was indicated by enzymatic experiments that verified the presence of active cellulase, protease, and chitinase in these formulations. Certain biofertilizer treatments produced comparable plant growth performance to commercial AB fertilisers, demonstrating the viability and sustainability of using materials derived from organic waste in agriculture. Furthermore, factorial and surface plots demonstrated strong synergistic interactions between elements such as BSF and EFB, thereby validating their combined efficacy in promoting enzymatic activity and early seedling development.

Conclusion: In conclusion, the findings of this study indicated that there is considerable potential in converting organic wastes into effective biofertilizers for sustainable agriculture. These results highlight how feasible it is to incorporate these biofertilizers into conventional farming systems in order to lessen reliance on chemicals, increase ecological resilience, and improve soil health. The study highlights how nutrient-rich waste can be effectively valorized through enzymatic and microbial processes, paving the way for cost-effective, environmentally friendly alternatives to synthetic fertilizers that support long-term agricultural productivity.

Keywords: Biofertilizers, *Amaranthus cruentus*, Agriculture, Enzymatic Technologies

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